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High Energy Cosmic Ray Modulation in March-June 1991

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ABSTRACT

The lowest galactic cosmic ray intensity since the initiation of continuous neutron monitor measurements was recorded in June 1991. Using neutron monitors and both surface and underground muon detectors we show that the solar-terrestrial phenomena between March and June 1991 modulated the galactic cosmic ray intensity above 45 GeV.

1. INTRODUCTION

A series of Forbush decreases were recorded at the earth in March through mid-June 1991. These large decreases were sufficiently frequent that the galactic cosmic ray intensity at the earth reached the lowest value recorded since routine neutron monitor measurements commenced in 1952. Figure 1 displays the daily average cosmic ray intensity from March through June 1991 as recorded by three cosmic ray detectors. Table 1 lists these detectors and their threshold and median rigidity responses.

TABLE 1. Cosmic Ray Detectors

Name	Detector	Threshold Rigidity	Median Rigidity
Inuvik	NM	1 GV	~9 GV
Inuvik	Muon	5 GV	~50 GV
Embudo	UG Muon	19 GV	~145 GV
Socorro	UG Muon	45 GV	~305 GV

2. SOLAR AND GEOMAGNETIC ACTIVITY

The sun was extremely active from March through June 1991 with 38 solar flares of optical importance $\geq$ 2B and 29 solar flares with a soft X-ray flux magnitude $\geq$ 1X. Most of the major events occurred in episodes of activity in March and June.

Major solar flares that occur near the central meridian of the sun (as viewed from the earth) often generate an interplanetary magnetic shock which, if the interplanetary conditions are favorable, interacts with the earth's magnetic field resulting in a geomagnetic storm. The arrival of an interplanetary shock is registered as a "Sudden Commencement" geomagnetic disturbance. There were 18 sudden commencement geomagnetic disturbances recorded at the earth during March-June 1991. This is another indicator of an extremely perturbed heliosphere, particularly in the immediate vicinity of the earth.

During major geomagnetic storms, the cosmic ray measurements often record a Forbush decrease - a rapid attenuation of the intensity as the interplanetary disturbance envelops and passes beyond the earth. The effect of these Forbush decreases may last for several days. Figure 1 reveals three major periods of cosmic ray attenuation: March, April and the end of May through the first part of June.

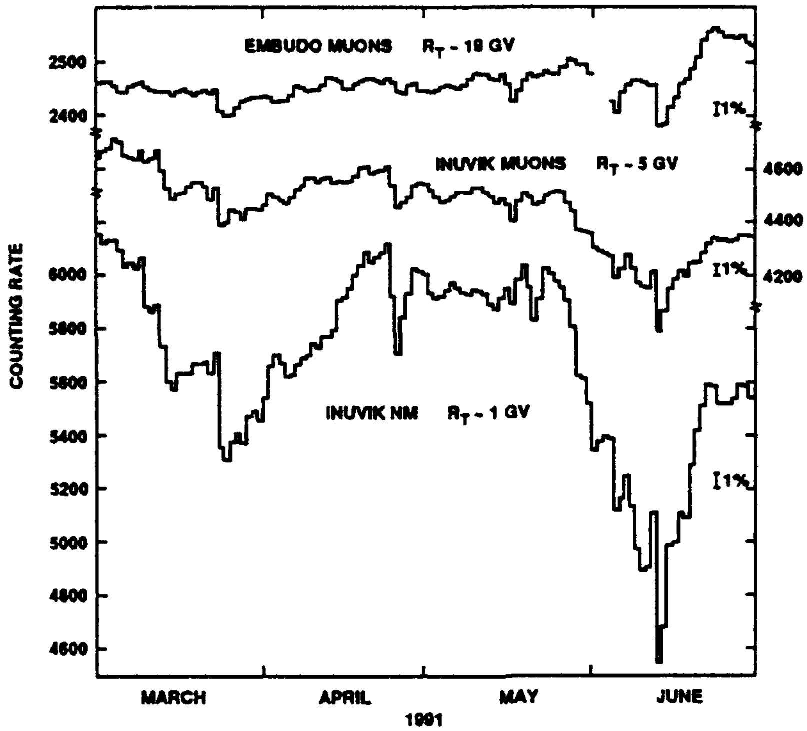

Figure 1. Daily averages of the cosmic ray counting rates during March through June 1991. The scale factor for the Embudo telescope is 128; the scale factor for each of the Inuvik detectors is 100. The threshold rigidity for each detector is identified.

3. MARCH 1991

The March 1991 solar activity was associated primarily with three active regions passing across the solar disk. The largest cosmic ray decrease of this period was on 24 March with the Embudo underground telescope recording a 4% decrease in the hourly values as illustrated in Figure 2. This figure also shows that the unusual spatial modulation present at that time (Shea and Smart, 1993) affected particles in excess of 19 GV. Unfortunately there was a malfunction with the camera at the Socorro underground detector at this critical time (Murphy, 1949).

4. APRIL-MAY 1991

A smaller disturbance, recorded on April 26, is evident in both Inuvik detectors, but is barely discernible in the Embudo record. All three detectors record a small decrease on 17 May although another decrease a few days later is recorded primarily by the neutron monitor.

5. MAY-JUNE 1991

The extended cosmic ray decrease during this period commenced around 28 May - well before solar region 6659 rotated over the eastern limb of the sun. Six sudden commencement geomagnetic disturbances were recorded at the earth from 4-17 June. Figure 3 illustrates the cosmic ray intensity recorded by four detectors from 11-14 June. Taking the cosmic ray intensity values at 19-21 UT on 12 June as a baseline, the cosmic ray intensity decreased by 3, 5, 8, and 17 percent at the Socorro, Embudo, Inuvik muon and Inuvik neutron monitors respectively. The lowest (hourly) intensity recorded by the Inuvik monitor was ~40% below the monthly average of May 1965 which was the highest monthly value between cycles 19 and 20.

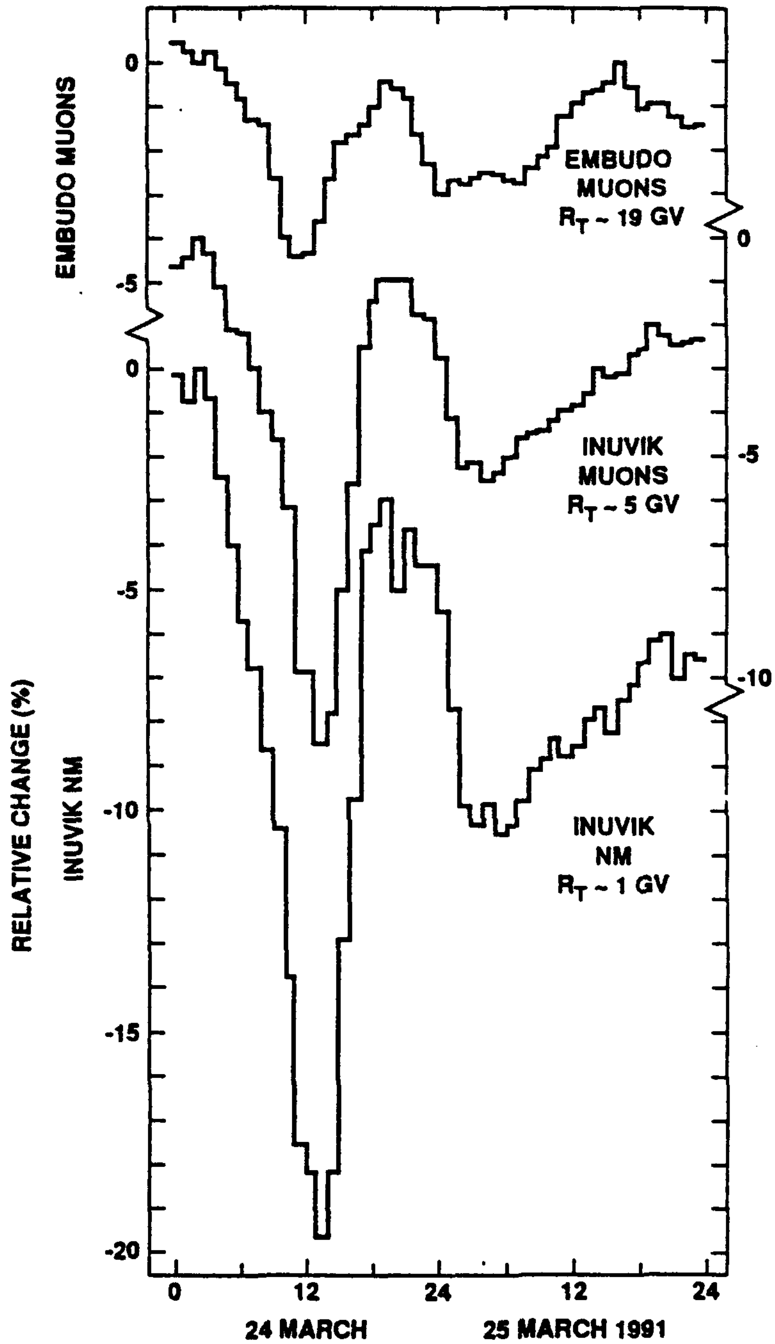

Figure 2. Relative changes in the cosmic ray intensity on 24-25 March 1991 as recorded by three detectors. The intensity between 02-03 UT on 24 March was taken as the 100% level.

5. SUMMARY

We have presented data showing that the solar activity and interplanetary disturbances in March-June 1991 combined to establish an all-time cosmic ray low as recorded by neutron monitors (since the start of routine monitoring in 1952). The interplanetary disturbances in June were sufficient turbulent to appreciably attenuate the cosmic ray intensity above 45 GeV.

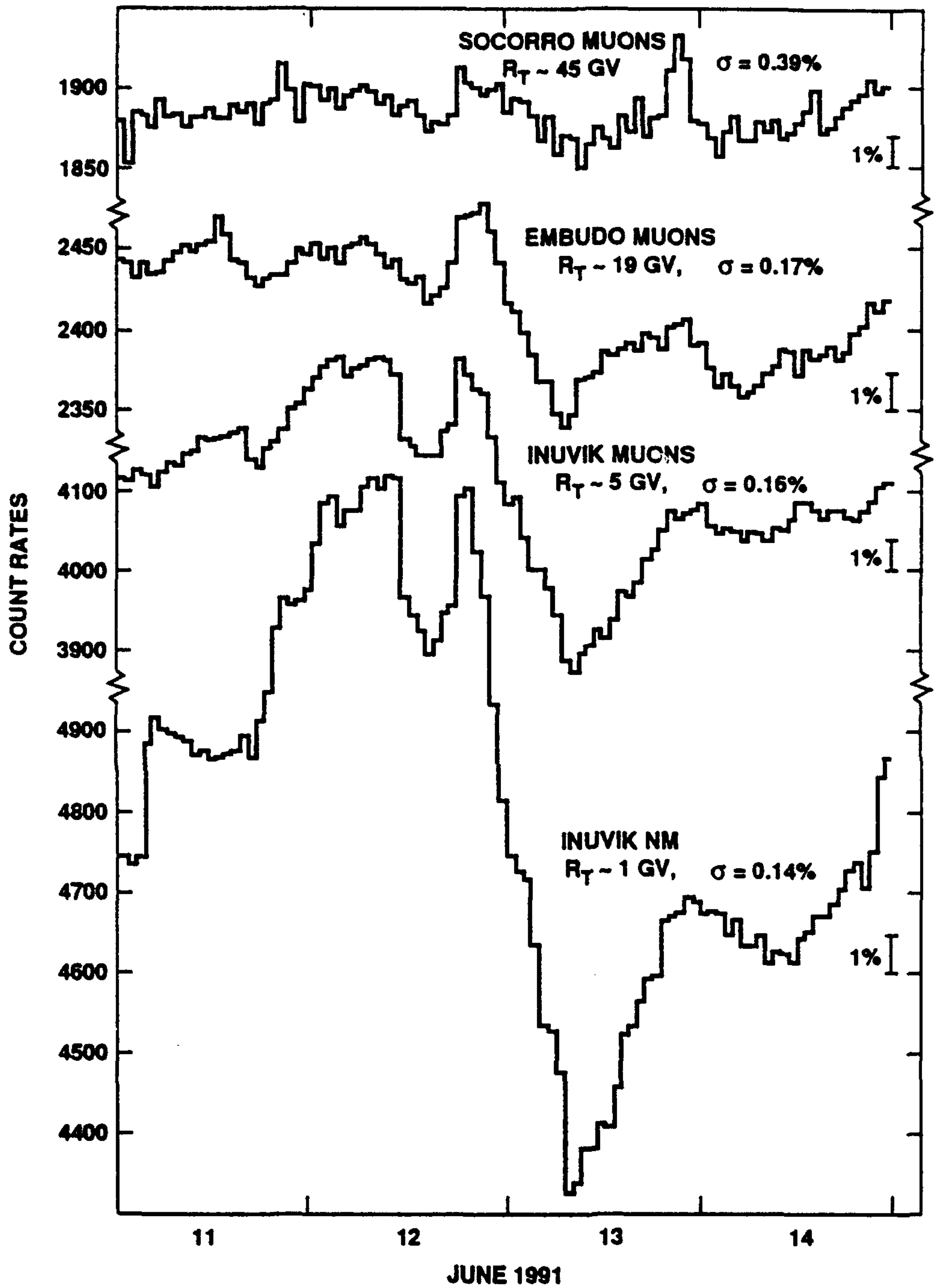

Figure 3. Cosmic ray counting rates on 11-14 June 1991. The scale factor for the Socorro telescope is 32, for the Embudo telescope is 128; the scale factor for each of the Inuvik detectors is 100. The threshold rigidity for each detector is identified.

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Murphy, E.: 1949, As quoted in the book, Murphy's Law, by A. Bloch, Price/Stern/Sloan Publishers, Inc., Los Angeles.

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